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PHYSICAL AND COOKING PROPERTIES OF NATURALLY AGED BROWN RICE

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ABSTRACT

The objective of this work was to determine some of the physical properties of naturally aged brown rice which may influence the rice processing operations. The physical properties Length or Longitudinal (L), Width (W), Thickness (T), Mass (M) and Volume (V) were measured and the following results were obtained: the average Length, Width, Thickness, Equivalent diameter, Sphericity, Aspect ratio, Surface area, Bulk density, true density, Porosity, 1000 grains weight and Angle of repose were 4.81 mm, 2.12 mm, 1.84 mm, 3.18 mm, 40.74%, 0.42, 26.58 mm^2, 740.6 kg/m^3, 1276.32 kg/m^3, 43.18, 19.53 g and 30.68^o respectively. From the color analysis of brown rice, L*, a* and b* values were ranged from 58.10 to 62.19, 4.23 to 6.73, and 22.41 to 24.29 respectively. The calculated cooking properties like Optimum cooking time, Elongation ratio, Solid loss in gruel and Width expansion ratio were 25.88 mins, 1.39 %, 3.53 and 1.74 respectively. The information of the present study would be useful for designing the post-harvest machineries for processing and storage structures in food processing industry.

KEYWORDS: Brown Rice, Physical Properties, Colour Values, Cooking Properties

INTRODUCTION

Rice is one of the leading food crops in the world and the staple food for more than half of the world's population. India has the largest harvested area in the world and produces over 130 MT of paddy every year. Commonly rice contributes for 40 to 80 per cent of the total calorie intake of Asian diet (Hossain *et al*., 2009; Cai, *et al.*, 2011). Brown rice, which is hulled directly from rough rice, consists of a bran layer (6–7% of its total weight), embryo (2–3%) and endosperm (about 90%) It contains more nutritional components, such as proteins, lipids, dietary fibres, vitamins and minerals, than white rice (Chen *et al*., 1998).These nutrients exist mainly in the germ and bran layers of the rice grains, but the germ and bran layers are almost removed during the milling process from brown rice to white rice, which is primarily consumed. Brown rice has become a popular health food. Consumption of brown rice reduces type 2 diabetes because it is rich in fiber, vitamins and minerals. Fresh brown rice contains more nutrients; hence it needs to be stored at low moisture content. Varietal properties such as grain size, shape, thousand-kernel weight, and hardness and bulk density affect the grain quality. Rice is typically consumed as cooked rice, although a small amount is used as an ingredient in processed foods.

The knowledge of physical and cooking of grain materials are useful for designing appropriate machineries for process operations like sorting, drying, heating, cooling, milling and find the solutions to problems associated with these processes (Sahay and Singh, 1994). These properties are important in the construction of storage facilities and the calculation of the dimensions of holding bins of a given capacity (Thompson and Ross, 1983).

MATERIALS AND METHODS

The paddy grains used in this study were obtained from local farmer nearby College of Food and Dairy Technology, Chennai, India. The grains were dried and cleaned manually and foreign matters such as stones, straw and dirt were removed. The dried and cleaned paddy samples were stored for a period of six months and then dehusked to obtain brown rice. The methods adopted for estimating these parameters are detailed below.

Physical Properties

Size Characteristics

Linear dimensions of grains were measured with micrometer having 0.01 mm accuracy. Grain length (L), width (W) and thickness (T) were measured in five replicates of ten kernels per sample (AdekoyeniOludare *et al.* 2012).

Equivalent Diameter (Dp)

The equivalent diameter (De) in mm considering a prolate spheroid shape for brown rice was determined by using expression as described under (Mohsenin, 1986).

$$D_p = \left(4L\left(\frac{W+T}{4}\right)2\right)^{1/3}$$

Sphericity (Φ)

The sphericity (*ø*) defined as the ratio of the surface area of the sphere having the same volume as that of the grain to the surface area of the grain was determined using (Mohsenin, 1986).

$$\emptyset = \frac{(LWT)^{1/3}}{L}$$

Aspect ratio (R_e)

The aspect ratio (Ra) was determined by using following formulae (Varnamkhasti *et al.*, 2008).

$$R_e = \frac{W}{L}$$

Surface Area

Surface area (S) were of brown rice was calculated by using different expressions (Jain and Bal, 1997).

$$S = \frac{\pi B L^2}{(2L - B)}$$

Where, $B = \sqrt{WT}$

Bulk Density

Milled rice kernels from different treatments were poured into a certain known volume from a fixed height and mass of samples occupying the volume was determined. Ratio was calculated as g/cc (Narpinder Singh *et al*. 2005).

True Density

The true density defined as the ratio between the mass of paddy and the true volume of the grain, was determined using the toluene displacement method. Toluene was used in place of the water, because it is absorbed by grains to a lesser extent. The volume of toluene displaced was found by immersing a weighted quantity of paddy in the toluene (Mohsenin, 1986).

Porosity

Porosity is the percentage of air between the particles compared to a unit volume of grains. It was calculated using the following equation **(**Jain and Bal, 1997).

$$\varepsilon = \frac{\rho_t - \rho_b}{\rho_t} X\ 100$$

Where, ε - porosity ρ_t - true density (kg/m^3), ρ_b- bulk density (kg/m^3)

Thousand Grains Mass

This was carried out by counting 100 kernels and weighing them in an electronic balance and then multiplied by 10 to give the mass of 1000 grains (Gayin, *et al*. 2009).

Angle of Repose

To determine the angle of repose of the paddy grains, a tube with 110 mm diameter and 120 mm height was kept vertically on a horizontal floor and filled with the sample from a height of 150 mm. The tube was slowly raised over the glass floor so that whole material could slide and form a heap. The angle of repose was calculated using the following equation (Jha, 1999).

$$\theta = tan^{-1}[\frac{2H}{D}]$$

Where, θ is the angle of repose in degrees, H and D are the height and diameter of the heap in mm, respectively.

Analysis of Colour Values

Colour of rice was tested using Hunter Lab Mini scan XE plus separate colorimeter (Model No. 45/0-L, Reston Virginia, USA) with geometry of diffuse/80 (sphere- 8mm view) and an illuminant of D65/10deg. The instrument was calibrated with black and white tile (L*=94, a*=1.10 and b*= 0.6) every time before the colour was expressed as L* (brightness), a* (redness) and b* (yellowness). Average value for each colour parameter was determined by taking observation from three different places from each brown rice sample.

Cooking Properties

Optimum Cooking Time

Head rice (2g) samples were taken in a test tube from each treatment and cooked in 20 ml distilled water in a boiling water bath. The cooking time was determined by removing a few kernels at different time intervals during cooking and pressing them between two glass plates until no white core was left (AACC, 2009).

Elongation Ratio

Cumulative length of 10 cooked rice kernels was divided by length of 10 uncooked raw kernels and the result was reported as elongation ratio (AACC, 2009).

$$Elongation\ ratio\ (\%) = \frac{X_C}{X_{UC}}\ X\ 100$$

Where, X_{UC} and X_C are the length of 10 uncooked and cooked kernels, respectively.

Solid Gruel Loss

Head rice samples (2g) in 20 ml distilled water, were cooked for minimum cooking and the gruel were transferred on several washings and made to volume with distilled water. The aliquot having leached solids was evaporated at 110 ^{0} C in an oven until completely dry. The solids were weighed and percent gruel solids were reported (AACC, 2009).

Width Expansion Ratio

Cumulative width of 10 cooked rice kernels was divided by width of 10 uncooked raw kernels and the result was reported as width expansion ratio (Hua Han Chen *et al*. 2012).

RESULTS AND DISCUSSIONS

Physical Properties

A summary of physical properties of brown rice was analyzed is shown in table 1. A Physiochemical property of brown rice was evaluated to provide important facts in determining their appropriate uses (Majzoobi*et al*., 2008).The average brown rice length, width and thickness were found to be 4.81, 2.12 and 1.84 mm, respectively. The importance of size and other characteristics axial dimensions used to determine aperture size and other parameters in machine design have discussed by Mohsenin (1986).

The equivalent diameter ranged from 3.03 to 3.28 mm, while the corresponding surface area ranged from 23.80 to 29.84 mm. The surface area of brown rice used to determine the shape of the rice.

It is seen from (Table 1) that the sphericity and aspect ratio of the kernels varied from 37.40 to 43.36 %, 0.24 to 0.61, respectively. Sphericity indicates the shape of the grains and the mean value is 40.74%. Aspect ratio is an indicator of a tendency towards an oblong shape.

The true density value lies within 1270.81 to 1284.42 kg/m^3. The value of true density indicates that, the kernel density is higher than water, which is the important property in case of food grains during wet cleaning, as a kernel does not float on water. The porosity of the kernels was found to be 43.18 ± 1.34.

The true density value lies within 736.49 to 749.85 kg/m^3. To determine the weight of product in the hopper, knowledge of bulk density is necessary. The knowledge of bulk density is useful for the design of silos and hoppers for grain handling and storage (Nalladulai *et al*., 2002). Thousand grain weight of brown rice was 19.53g. Weight is an important parameter to be used in the design of cleaning grains using aerodynamic forces Oje K and Ugbor EC, 1991).

Angle of repose finds its application in hopper designing which determines the maximum angle of a pile of grain with the horizontal plane, while the hopper wall’s inclination angle should be greater than the angle of repose to ensure the

continuous flow of the materials by gravity.

Colour Values

The colored rice varieties found to be potent source of antioxidants (Sompong *et al*., 2012). The more the color of brown rice kernel more energy it take to polishing and difficult to process (Shittu *et al*., 2012; Saikia *et al.*, 2012). In this study, L*, a* and b* were found to be 60.16, 5.31 and 23.57 respectively. Chrastil (1990) reported that yellowness of milled rice increased during storage at ambient temperature also due to Maillard reaction.

Table 1: Physical Properties of Brown Rice

Physical Properties	Min Value	Max Value	Mean Value	SD
Length (mm	4.74	4.89	4.81	0.05
Width (mm)	2.02	2.20	2.12	0.06
Thickness (mm)	1.79	1.90	1.84	0.04
Equivalent diameter(mm)	3.03	3.28	3.18	0.10
Sphericity (%)	37.40	43.36	40.74	1.12
Aspect ratio	0.24	0.61	0.42	0.14
Surface area (mm^2)	23.80	29.84	26.58	2.06
Bulk density (kg/m^3)	736.49	749.85	740.6	4.59
True density (kg/m^3)	1270.81	1284.42	1276.32	4.45
Porosity	41.69	45.07	43.18	1.34
Thousand kernel weight(g)	18.81	20.84	19.53	0.78
Angle of repose (degree)	29.93	31.32	30.68	0.54

Table 2: Colour Values of Brown Rice

L*	58.10	62.19	60.16	1.46
a*	4.23	6.73	5.31	0.95
b*	22.41	24.29	23.57	0.67

Table 3: Cooking Properties of Brown Rice

Optimum Cooking Time	25.85	25.91	25.88	0.02
Elongation ratio	1.35	1.43	1.39	0.02
Solid loss in gruel	3.50	3.59	3.53	0.03
Width expansion ratio	1.17	3.59	1.74	0.02

Cooking Properties

The optimum cooking time ranges between 25.85 to 25.91 minutes. Cooking time is directly affected by the gelatinization temperature of starch and by protein content. Increase in storage period of rice changed the cooking properties and gelatinization characteristics of granules, resulting in decrease in optimum cooking time. Similar results were reported by Haifeng *et al.* (2001)

The elongation ratio was found to be 1.39±0.02. In general, elongation ratio of cooked rice increases during aging process as a result of changes in starch granule leading to greater resistance of the grain to disintegration during cooking

Solid gruel loss (3.53±0.03%) of aged rice is lesser than the freshly harvested brown rice. The smaller amount of solids loss after processing might be related to the strengthening of cell walls of rice grain, which can resist the grain swelling during cooking (Desikachar and Subrahmanyan, 1959). In addition, the complex formation between free fatty

acids and amylose resulted in lower water-solubility starch.

The width expansion ratios were found to be 1.74±0.02 %. The increase of volume of the treated samples after cooking might be due to the fact that cell walls of dried brown rice were more strengthened, due to starch gelatinization, and could maintain the hexagonal shape, which led to higher water adsorption (Desikachar and Subrahmanyan, 1959).

CONCLUSIONS

Investigations conducted on naturally aged brown rice variety indicated differences in the physiochemical, proximate and cooking properties. This results are useful in designing of milling equipments and storage structures. Also useful in the preparation of new rice based food products.

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